Collision centrality determination in the CBM experiment*

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The magnitude of the impact parameter b in a heavy-ion collision is not known experimentally. Estimating b is important for the study by CBM of many physics observables, e.g. the event-by-event fluctuations of conserved quantities at mid-rapidity or collective flow. The multiplicity of produced particles in the overlap zone of the nuclei can be used as an experimental proxy of the b value. All events are sorted in centrality classes, with most central one being the collisions with highest multiplicity ($b \approx 0$) of the produced particles and peripheral one with the lowest multiplicity (when b value is about the sum of the radii of the two nuclei). Since the b value and particle multiplicity are correlated only on average, for a given multiplicity (centrality) class of events only an average $\overline{b}$ value and its spread σ_b can be estimated.

The projectile Spectator Detector (PSD) of the CBM experiment is designed to register forward spectator nucleons and fragments emitted in nucleus-nucleus collisions at very small polar angles. The multiplicity of spectators can also be used as an independent way to determine centrality. In the case of spectator measurements, the most central events correspond to a low spectator multiplicity (small energy deposition in the PSD), while peripheral events result in a large amount of spectators (large energy deposition in the PSD).

The performance of the centrality determination was studied using the DCM-QGSM heavy-ion collision event generator [1]. The PSD was either used as a standalone detector utilizing correlations between the energy deposited in different PSD subevents (segments), or in a combination with the CBM Silicon Tracking System (STS) which measures the multiplicity of produced particles at midrapidity. In the case of the PSD standalone analysis, it was required to have at least 40 GeV of energy in the PSD1 subevent or a total energy in two PSD2 and PSD3 subevents above 15 GeV to exclude very peripheral collisions with only few heavy fragments.

Figure 1 shows the performance of the centrality determination for Au+Au collisions at E_{beam} = 10 AGeV. The PSD is positioned at 8 m from the target. Centrality classes are defined by using various detector subevent combinations. The top panel shows the average impact parameter value $\overline{b}$ (central value) and σ_b (as the error bars) versus the centrality estimate from different subevent correlations. The bottom panel presents the same information in terms of impact parameter resolution $\sigma_b/\overline{b}$ of different centrality estimators. The $\overline{b}$ and σ_b were determined from Gaussian fits of the impact parameter distribution for a given centrality class.

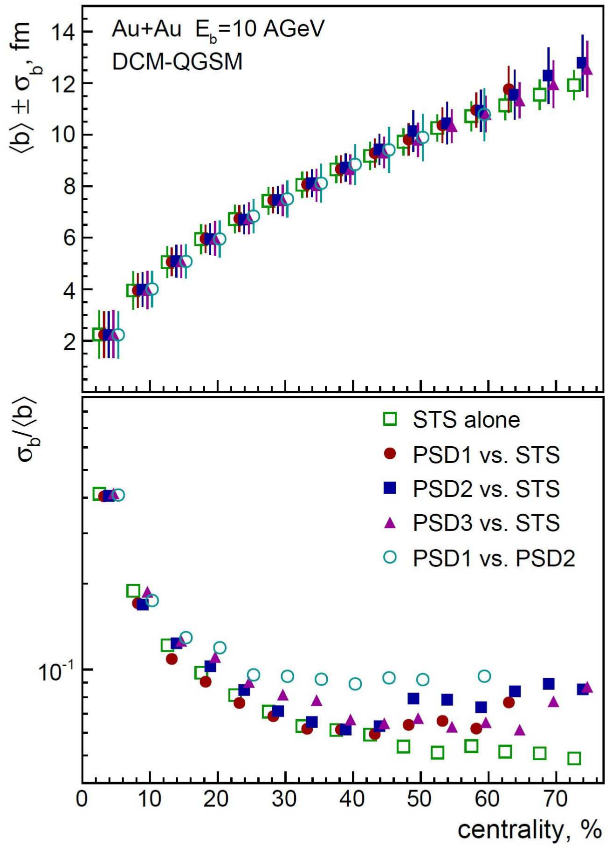

Figure 1: Average $\overline{b}$ and width σ_b of the impact parameter distribution (top); impact parameter resolution ($\sigma_b/\overline{b}$) vs. centrality (bottom).

The results in Fig. 1 demonstrate that the PSD can be used standalone for the centrality determination and, depending on the collision energy, has a comparable impact parameter resolution $\sigma_b/\overline{b}$ to that of the STS. This provides an independent method in the CBM experiment for the centrality determination with detected spectator fragments. When used together with the STS detector, the PSD helps to improve the overall centrality determination in the centrality range of 0-40% and allows for centrality determination in narrow classes with a width of at least 5%.

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References

[1] The SHIELD code, www.inr.ru/shield/index.html.

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